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DISCUSSION PAPER: SUBSIDENCE RESEARCH IN THE SYDNEY COALFIELD

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DISCUSSION PAPER: SUBSIDENCE RESEARCH IN THE SYDNEY COALFIELD

by

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SUMMARY

Existing guidelines for the safe working of undersea coal reserves suggest that between 8.75 mm/m (N. America) and 10 mm/m (U.K.) of tensile strain associated with subsidence formation can be induced at seabed before the risk of water occurrences to mine workings becomes unacceptable. The applicability of existing guidelines to the Sydney Coalfield is uncertain, since they are derived from land truthed data which has been extrapolated to undersea conditions, rather than empirically derived from seabed truthed data. It is therefore proposed to initiate a major research effort to monitor subsidence development over the undersea workings of the Sydney Coalfield.

This report provides a discussion document for the proposed subsidence monitoring program and details of the proposed studies.

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DOCUMENT DE TRAVAIL: RECHERCHE SUR LES POSSIBILITÉS D'AFFAISSEMENT DANS LE BASSIN HOUILLER DE SYDNEY

par

T.R.C. Aston*

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Les directives actuelles concernant la sécurité des travailleurs dans les réserves de charbon sous-marines suggèrent que des déformations de tension comprises entre 8.75 mm/m (en Amérique du Nord) et 10 mm/m (au Royaume-Uni), et qui sont associées à la possibilité d'affaissement, peuvent se produire au fond de la mer avant qu'il y ait risque de venues d'eau et qu'ainsi les conditions de travail dans la mine soient inacceptables. On n'est pas certain de pouvoir appliquer les directives actuelles au bassin houiller de Sydney, étant donné qu'elles sont dérivées des données applicables dans les champs d'exploitation minière du charbon qui ont été extrapolées pour des conditions d'exploitation sous-marines, plutôt que d'être dérivées de données empiriques. En conséquent, on suggère de commencer à effectuer des travaux de recherches importants sur les possibilités d'afaissement du chantier houiller de Sydney.

Ce rapport fournie un document de travail sur le programme de contrôle d'affaissement proposé et les détails de l'étude suggérée.

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INTRODUCTION

Coal reserves in the Sydney coalfield are located in strata beneath the Atlantic Ocean off the coast of Cape Breton, Nova Scotia. The Cape Breton Development Corporation is currently working three submarine mines: Lingan, No. 26 and Prince. Each of these mines is working a single seam by longwall methods with pillars between adjacent mining panels.

The Cape Breton Development Corporation has a new mine, Donkin-Morien, under construction and has developed feasibility studies for two further mines: Glace Bay and Lingan-Phalen. These new mines will result in multiple-seam total extraction of submarine coal measures in the Lingan, Donkin-Morien and Glace Bay areas.

Such multiple-seam total extraction mining is new to the Cape Breton Development Corporation, although these techniques have been practiced in North-East England. The potentially serious implications of seawater inrushes in submarine mines has led to the preparation of this report. It is hoped that through research, the Cape Breton Coal Research Laboratory will be able to establish hard data truthed subsidence models for the Sydney coalfield and provide guidelines for the safe working of submarine coal measures in the largest coalfield in Eastern Canada (3×10^9 tons of reserves with 1.3×10^9 tons recoverable with existing technology, N.S. Dept. of Mines and Energy Statistics).

Existing guidelines for the safe working of undersea coal reserves suggest that between 8.75 mm/m (N. America) (1) and 10 mm/m (U.K.) (2) of tensile strain associated with subsidence formation can be induced at seabed before the risk of water occurrences to the mine workings becomes unacceptable. The present guidelines are based on land truthed data which has been extrapolated to undersea conditions, rather than empirically derived from seabed truthed data. If the guideline value is overestimated large reserves of economically viable coal are effectively sterilized, which reduces the working life of the mine. Similarly, a value which is underestimated increases the risk of a major water occurrence within the workings.

The applicability of existing guidelines to the Sydney coalfield is uncertain. It is therefore proposed to initiate a major research effort

to monitor subsidence development over the undersea workings of the Sydney coalfield. The objects of the program are to measure subsidence formation, produce effective prediction techniques and establish safe working guidelines. The magnitude of permeability changes within the intervening strata associated with subsidence formation will be determined since this property in conjunction with the structural geology, dictates the amount of ingress water.

This report provides a discussion document for the proposed subsidence monitoring program and details of the proposed studies. It is anticipated that further discussions based on this document will be held to refine the research program.

THE SUBSIDENCE PROFILE

Before outlining the proposed research program it is necessary to consider the nature of a subsidence profile and the parameters available for measurement.

When the extracted area behind a longwall face is left to cave naturally, maximum subsidence experienced at surface will normally be 85-90% of the extracted seam height. However, if a method of stowing is used then the maximum subsidence experienced is reduced. Table 1 shows maximum subsidence as a percentage of extracted seam height for a variety of British conditions.

Condition	
Natural Caving	90%
Solid Caving	45%
E. Midlands Coalfield 1st seam working	80%
E. Midlands Coalfield 2nd and subsequent seam working	90%

Table 1 Maximum Subsidence as a Percentage of Extracted Seam Height for a Variety of Mining Conditions

Consideration of a subsidence profile reveals that any given point on the surface will be displaced both vertically downwards and horizontally towards the central working axis. Resultant differential displacement will therefore result in a zone of apparent extension on the convex section of the profile and a complimentary zone of compression on the concave section. Zones of compression and tension along with three of the basic ground movements which can be measured at surface are shown in Figure 1.

The limit at surface to which the effect of subsidence can be measured is known as the 'angle of draw'.

During subsidence profile formation, in addition to the development of a transverse profile normal to the face direction, a dynamic or longitudinal profile is also formed parallel to the direction of working. Net result is the formation of a subsidence trough with associated zones of tensile and compressive strain, shown diagrammatically in Figure 2. The four basic parameters of ground movement develop simultaneously on both transverse and longitudinal profiles.

PROPOSED RESEARCH PROGRAM

A comprehensive research program for monitoring subsidence and determining satisfactory guidelines for the maximum permissible tensile strain that can be induced at seabed must be a multi-phase, long-term project. The expected duration of the program is eight years.

The proposed program can be divided into two distinct parts:

1) Theoretical and Modelling Studies
2) Field Instrumentation Studies

In both parts, a comprehensive review would be initiated as the first phase, in order to determine 'state of the art' theories and techniques. A breakdown of the major program components is given in Appendix 1.

THEORETICAL AND MODELLING STUDIES

Initially, a suite of programs would be developed enabling subsidence profiles to be calculated using current prediction methods such as the

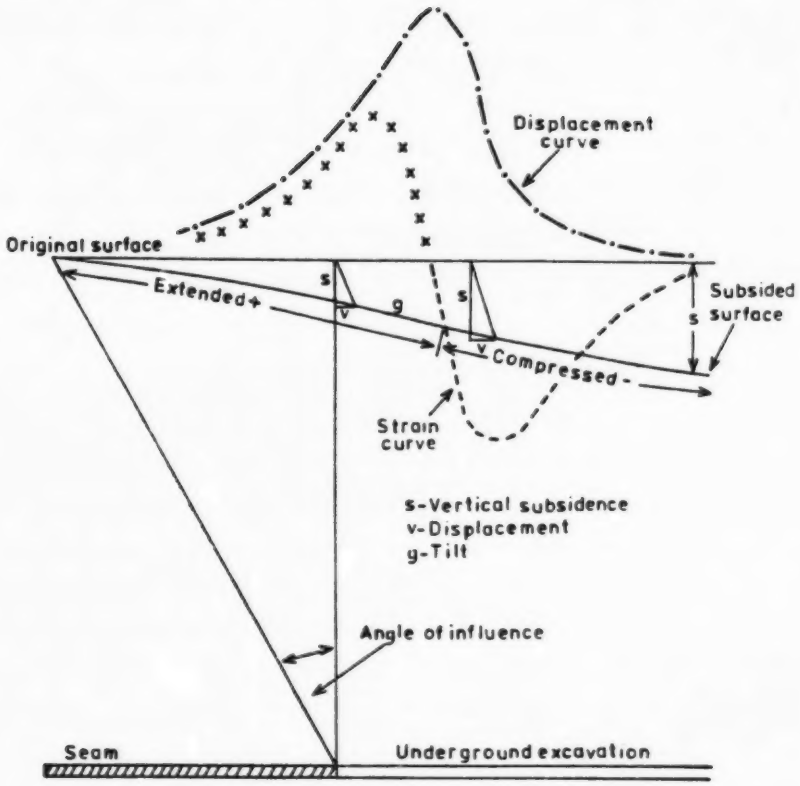
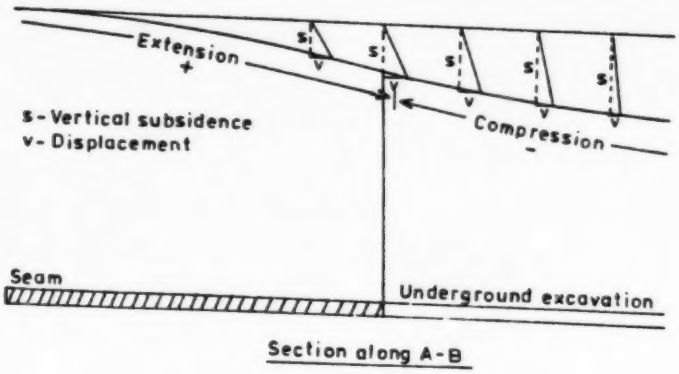


Figure 1 Elements of Ground Movement Associated with Subsidence Profile Formation



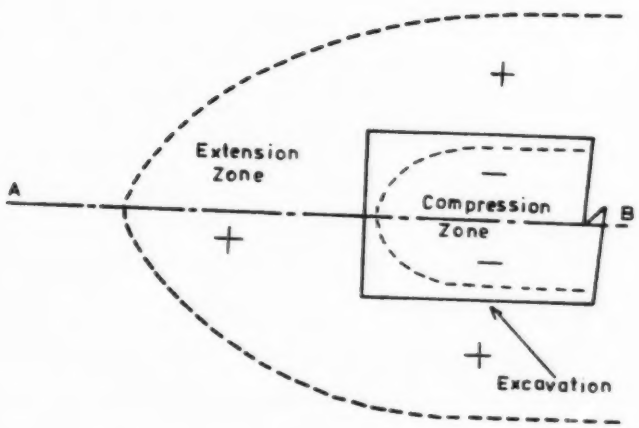


Figure 2 Zones of Tensile and Compressive Strain Developed around a Longwall Extraction

Subsidence Engineers Handbook (3) and the European 'Sphere of Influence' theory (4) (5). Alternatively, if these programmes already exist, they could be acquired and made compatible with existing CANMET computing facilities. Concurrently, a series of models would be developed based on numerical analysis. These latter models could incorporate either two dimensional finite element plastic yielding rock and/or three dimensional finite/boundary element theories. Selected world-wide data collected during the review phase, would be input to the current prediction methods and used to compare these techniques and also provide calibration data for the numerical analysis models.

An examination of the available Sydney coalfield subsidence data would be undertaken. Suitable data, where available, would be collected and input to the modelling studies. A broad comparison could then be drawn between the behaviour of the Sydney coalfield and selected coalfields elsewhere in the world.

A detailed listing of the various phases comprising this part of the program are given in Appendix 2.

FIELD INSTRUMENTATION STUDIES

This part of the program can be divided into three main sections:

1) Monitoring Subsidence Profile Formation
2) Monitoring In situ Permeability Changes
3) Undermining Offshore Boreholes

1) Monitoring Subsidence Profile Formation

At present a contract is in the process of being 'tendered' which will examine instrumentation schemes for monitoring the formation of subsidence profiles and their associated zones of tensile and compressive strain at seabed. Once the available schemes have been identified, a field data collection program will be initiated to monitor seafloor subsidence in the Sydney coalfield. The results will be input to the models assessed as being most applicable, from the first part of the program.

It should be noted that in all probability data will only be available from a limited number of sites. The data collection scheme should therefore be extended to obtain sufficient data to allow a high degree of refinement in the proposed prediction models. Sufficient data should also be collected to allow guidelines to be drawn up for the safe working of multi-seam workings beneath the sea.

2) Monitoring In Situ Permeability Changes

In order to allow development of an effective prediction model, it is necessary to know the natural permeability regime of the intervening strata as well as the magnitude of permeability changes induced by the subsidence profile. However, rather than discuss the variety of instrumentation schemes available for monitoring permeability changes, it is considered more important to identify those areas surrounding a longwall panel from which data will be required for input to the model. The three areas requiring investigation are:

1) In front and Above the Face Line
2) Above the Goaf Area
3) Above the Ribside Zone

3) Undermining Offshore Boreholes

Offshore exploration boreholes are currently back filled with concrete along their entire length. Uncertainty associated with the back filling has led the Cape Breton Development Corporation to establish pillars around such boreholes. These pillars complicate mine planning and often result in the sterilization of large coal blocks ($+ 10^6$ tons).

With the introduction of multi-seam mining, the opportunity exists to drive a borehole from upper seam workings to a lower seam. This borehole could be monitored as the lower seam workings pass the installed site in order to assess permeability changes around the borehole and the success of existing concrete back filling technology. Such an effort would also provide useful data on permeability changes occurring in the goaf area through which the monitored borehole passes.

Alternatively a land based longwall panel in comparable geology could be monitored with one or more offshore type boreholes sunk from surface.

OPERATIONAL SEQUENCE OF PROGRAM

With the exception of the theoretical and modelling studies which have already been described, the sequence of events involved in the field instrumentation studies are:

1) Objectives of Program
2) 'State-of-the-Art' Review
3) Choice and Acquisition of Instrumentation
4) Choice and Installation of Site
5) Data Collection and Analysis
6) Presentation of Results
7) Integrate Results into the Subsidence Prediction Models
8) Repeat Operations 1-7 for Additional Data and Refinement of Prediction Models.

A detailed listing of the various phases comprising the field instrumentation studies is given in Appendix 3.

CONCLUSION

The future of underground coal mining in the Sydney coalfield is dependent upon the establishment of new multi-seam total extraction mines in the submarine coal measures. Effective technical guidelines to control seawater ingress to the workings must be established so that excessive near surface tonnage is not sterilized through overly conservative tensile strai limiting criteria. While the project described in this report is intended to address conditions in the Sydney coalfield, it will also find applicatio elsewhere in the longwall mining of reserves beneath large surface or sub-surface water bodies.

While resources (persons and dollars) have not been identified fo this project, it is apparent that resources required to implement a projec of this magnitude exceed the in-house capability of CBCRL.

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APPENDIX A

MAJOR PROGRAM COMPONENTS

TASK DESCRIPTION	TASK DURATION (YEARS)							
	1	2	3	4	5	6	7	8
1 Review existing subsidence theories/models.								
2 Develop subsidence computer programs.								
3 Collect and collate selected data for input to (2).								
4 Assess results from (3) and choose most applicable model(s).								
5 Assess/choose instrumentation schemes for seafloor subsidence monitoring.								
6 Initiate data collection scheme from (5).								
7 Input data from (6) into models (4) and assess results.								

	TASK DESCRIPTION	TASK DURATION (YEARS)							
		1	2	3	4	5	6	7	8
8	Repeat operations (6) and (7) for additional data and model refinement.				———	———	———	———	
9	Monitor in situ permeability changes associated with subsidence profile development	———		———	———	———	———	———	
10	Undermining offshore boreholes investigation.		———	———	———	———			
11	Integrate all results from Phases (7) to (10) into chosen subsidence model.						———	———	———
12	Present final prediction model and formulate safe guidelines for undersea working.							———	———

APPENDIX B

THEORETICAL AND MODELLING STUDIES

TASK DESCRIPTION	TASK DURATION (YEARS)							
	1	2	3	4	5	6	7	8
1 REVIEW EXISTING SUBSIDENCE THEORIES/MODELS								
1.1 Examine current prediction methods subsidence engineets handbook, area of influence, profile functions, others.	———	———						
1.2 Examine application of numerical analysis and semi analytical techniques for subsidence prediction.	———	———						
2 DEVELOP SUBSIDENCE (COMPUTER) PROGRAMS.								
2.1 Current prediction methods subsidence engineers handbook, area of influence, profile functions, others.	———	———						
2.2 Numerical Techniques: 2D Finite element plastic yielding rock. 3D Finite/boundary element theories.	———	———	———		———	———	———	
3 COLLECT AND COLLATE SELECTED DATA FOR INPUT TO (2)								

TASK DESCRIPTION	TASK DURATION (YEARS)							
	1	2	3	4	5	6	7	8
3.1 From the Sydney Coalfield.	———							
3.2 From Great Britain, Europe, U.S.A., Australia, S. Africa.	———	———						
4 ASSESS RESULTS FROM (3) AND CHOOSE MOST APPLICABLE MODEL(S).		———	———	———				

APPENDIX C

FIELD INSTRUMENTATION STUDIES

TASK DESCRIPTION	TASK DURATION (YEARS)							
	1	2	3	4	5	6	7	8
5 MONITORING SUBSIDENCE PROFILE FORMATION.								
5.1 Objectives of Program.								
5.2 'State of the art review'.								
5.3 Choice and Acquisition of instrumentation								
5.4 Choice and installation of site.								
5.5 Data collection, analysis and presentation of results.								
5.6 Integrate results into subsidence prediction models.								

TASK DESCRIPTION	TASK DURATION (YEARS)							
	1	2	3	4	5	6	7	8
5.7 Repeat Operations 5.2 - 5.6 for additional data and refinement of prediction models.				———	———	———	———	
6 MONITORING IN SITU PERMEABILITY CHANGES ASSOCIATED WITH SUBSIDENCE PROFILE FORMATION.								
6.1 Objectives of Program.		———						
6.2 'State of the art review'.		———	———					
6.3 Choice and acquisition of instrumentation.			———	———				
6.4 Choice and installation of sites.				———				
6.5 Data collection, analysis and presentation of results.				———	———			

TASK DESCRIPTION	TASK DURATION (YEARS)							
	1	2	3	4	5	6	7	8
6.6 Integrate results into subsidence prediction models.					———			
6.7 Repeat operations 6.2 - 6.6 for additional data and refinement of prediction models.			———	———	———	———	———	
7 UNDERMINING OFFSHORE BOREHOLES.								
7.1 Objectives of Program.		———						
7.2 'State of the art review'.		———						
7.3 Choice and acquisition of instrumentation			———	———				
7.4 Choice and installation of site.			———	———	———			